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Structural and electronic properties of Bi_2Te_3/Eu/Bi_2Te_3 films

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Bi_2Te_3 - one of the known topological insulators is considered as a promising material for multiple applications in next generation electronic or spintronic devices [1]. The crystal of Bi_2Te_3 is a semiconductor with the bulk energy bandgap of 0.3 eV. Its bandgap contains gapless, topologically protected surface states responsible for its exceptional magnetoelectric properties [2]. The time-reversal symmetry, responsible for linear dispersion of the surface states, can be broken to open a gap by different factors (e.g. Coulomb, magnetic and disorder perturbations).

Here we focused on the response of a Bi_2Te_3 surface to the disorder introduced by a layer of europium placed between the Bi_2Te_3 layers. Europium was selected due to its magnetic properties, directly related to its valency state; Eu^{3+} is non-magnetic (J = 0) while the Eu^{2+} has a large pure spin moment (J = 7/2) [3]. The applicability of the same element which may exhibit in in two different valency states (of which one is magnetically ordered and second is not) was crucial indicator of europium selection.

The growth of the multilayer structure of the Bi_2Te_3 and europium was realized in the MBE chamber. The films were grown on mica substrate with the following order of layer stack; 15nm thick Bi_2Te_3 layer, 0.5 or 2nm thick europium liner layer, 2nm thick Bi_2Te_3 top layer.

The structural characterization of grown layers was realized using the RHEED and LEED techniques. Crystalized in hexagonal phase 15nm thick Bi_2Te_3 is covered by partially textured polycrystalline europium liner, whereas the 2nm thick Bi_2Te_3 top layer shows a polycrystalline arrangement.

The electronic structure studies were conducted at each step of the growth procedure using the X-ray Photoelectron Spectrometer (XPS). Angle dependent measurements were conducted in order to observe in detail the Eu-Bi_2Te_3 interfaces. The chemical states of bismuth and tellurium were obtained from the detailed analysis of the Bi*4*f and Te*3*d multiplets. The chemical state and the valency state of europium were investigated by the analysis of Eu3*d* and Eu4*d* multiplets.

The analysis of the chemical shifts of the core levels as well as the relative changes in photoemission lines area ratio, allowed to conclude that
(1) within the examined system the layers are inter-mixing at room temperature,
(2) europium remains in divalent state,
(3) the exchange splitting of the Eu $4d_{5/2}$ core level is clearly resolved with a splitting of 0.9 eV,
(4) partial oxidation and/or reaction with Bi_2Te_3 layers leads to europium valency transition $Eu^{2+} \leftrightarrow Eu^{3+}$,
(5) the valency transition of europium entails shifting of the Te3*d* satellites.

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